ENERGY SECURITY FOR THE SUSTAINABLE MANAGEMENT OF REMOTE COMMUNITIES AND ISLANDS

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Certification of Authenticity

I hereby certify that the content of this report is the original and authentic work of the author, John M. Warren.

Signed,

John Macdonald Warren

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John M. Warren

Executive Summary

This paper argues that for remote communities and islands, investment in regional energy potentials decreases reliance on imported energy sources, creating energy security by ensuring a continuous and uninterrupted supply of affordable and environmentally friendly energy. Using the principals of Material Flow Management to identify regional energy potentials, remote communities create the opportunity for internal investment. The investment into and the activation of these resources further creates economic, social and environmental regional added value, helping to foster economic growth by re-invigorating the domestic economy.

Using the example of a typical remote island community, Marinduque, Philippines, this paper investigates the energetic potential of agricultural residues on the island. By developing the technical and financial case for Marinduque's first biomass-to-energy system based in the municipality of Santa Cruz, this paper demonstrates the financial, social and environmental added value created by the implementation of regenerative energy systems. By activating regional added values through the implementation of the Santa Cruz biomass to energy project, energy security on the island is increased, reducing the levelized cost of electricity and reducing the flow of financial capital off the island to pay for energy services.

In conclusion, this paper posits that regenerative energy systems add value to a region on multiple fronts and that by ensuring both short and long-term energy security, the activation of regional energy potentials creates the opportunity for investment and re-investment within the region, creating a virtuous cycle of sustainable economic and human development growth.

Definitions

Biomass Residues	Non-edible and otherwise 'waste' material as a byproduct from the production of usable biomass
Biomass-to-Energy	Energy production using biomass as fuel (e.g. combustion of wood pellets, or combustion of Methane from biogas)
Carbon Cycle	The natural circulation of carbon atoms as a result of the conversion of carbon dioxide into organic compounds through photosynthesis by plants which are in turn broken down and returned to the atmosphere once more as carbon dioxide (Biology Online, 2006)
Carbon Neutrality	Used to describe fuels that neither contribute nor reduce the amount of Carbon Dioxide into the atmosphere above levels naturally occurring in the Carbon Cycle
Certified Emission Reduction (CER)	A unit used in the Clean Development Mechanism to represent one ton of carbon dioxide equivalent either sequestered or abated through a registered project (Baker & McKenzie, 2012)
Circular Economy	Economic model emphasizing the use of and investment into regional material and energy potentials
Clean Development Mechanism	A Mechanism within the Kyoto protocol to encourage the implementation of greenhouse gas emission reducing projects in developing countries through the issue of certified emission reduction credits generated by the projects (UNFCCC, 2012)
Co-Generation	The simultaneous generation of usable electrical and thermal energy
Copra	Dried or cured coconut flesh
Debt	Money borrow by one party from another (Investopedia, 2012)
Energy Security	The ability to provide continuous and uninterrupted access to an affordable and environmentally sound supply of energy

Equity	The sale of common or preferred stock by a company with the intention of raising money for company activities (Investopedia, 2012)
Greenhouse Gases	Gases that contribute to the natural and anthropogenic warming of the earth's atmosphere by inducing radiative forcing
Human Development Index (HDI)	A tool developed by the United Nations to measure the level of social and economic development within a country based on life expectancy, years of education, expected years of education and income per capita (Investopedia, 2012)
Interest	The percentage paid on money borrowed over a defined period of time (Investopedia, 2012)
Internal Rate of Return (IRR)	"The rate of return that would make the present value of future cash flows plus the final market value of an investment or business opportunity equal the current market price of the investment or opportunity" (Investor Words, 2012)
Linear Economy	Economic model emphasizing the import of energy and materials for use within the system. Based on a cycle of debt and payment.
Material Flow Management (MFM)	"Management of material flows by the involved stakeholders and refers to the goal oriented, responsible, integrated and efficient controlling of material systems with the objectives arising from both the economic and ecological sector and with the inclusion of social aspects." (Helling, n.d., p. 25)
Net Present Value (NPV)	"The present value of an investment's future net cash flows minus the initial investment" (Investor Words, 2012)
Purchasing Power	The value of a currency expressed in the amount of goods and services that the currency can buy (Investopedia, 2012)
Regional Added Value (RAV)	Total revenue created by all factors of production within a defined system, less the cost of inputs into the system (CIPRA, 2008)
Remote Communities	Communities that are not connected to a regional grid structure. As such remote communities often suffer from high energy prices and lower levels of energy security

Return on Investment (ROI)	A measure of the performance of an investment used to evaluate and compare it's efficiency (Investopedia, 2012)

Part I: Energy Security for the Sustainable Management of Remote Communities and Islands

Introduction

As global population swells the impact of human settlement is felt more and more acutely. Energy and material consumption is currently coupled with economic and social development, putting greater strain on limited resources every day. Issues of energy security are not confined to the developed world, but affect the way in which the world develops. Addressing these issues will be a defining characteristic of the 21st century but it need not be a struggle.

Remote communities and in particular, islands, face the greatest challenges. Limited and dwindling fossil resources must be imported at great cost, which combined with steadily increasing prices leads to a greater degree of uncertainty in the provision of energy. This uncertainty affects not only the quality of life for the inhabitants, but the ability of these communities to develop. This cycle of negative reinforcement contributes to economic stagnation and entrenched or, systemic poverty.

Material Flow Management (MFM) is a tool that is designed to enhance regional energy and material flows. By maximizing regional potentials, MFM seeks to increase regional energy and material independence while simultaneously creating opportunities for investment and economic development within the region. The creation of circular economies, the internal investment and reinvestment in energetic, material, social and financial flows, helps to decrease the impact of energy dependence and in turn breaks down the cycle of poverty entrenched in the current economic paradigm.

This report argues that the introduction of MFM techniques into remote communities, maximizing regional material flows, not only encourages the investment into environmentally sound technologies and practices, but also creates a system of Regional Added Value (RAV) that in turn stimulates local economies, increasing the rate of economic development, while breaking down systemic poverty. This report demonstrates through the case study of Marinduque, Philippines, that by changing the manner in which regional material flows are managed, investment in environmentally sound technologies yields both short-term and long-term economic, environmental and social value.

Understanding Energy Security - Concept Development

Remote and Island Communities

Remote communities are those that are, "not connected to a regional grid structure," be it electrical or natural gas (Natural Resources Canada, 2005, p. 7). Although autonomous in energy production, if electrified, they must each own and operate their own electrical generation and distribution infrastructure. There are multiple disadvantages associated with operating an electrical grid 'island':

1. Remote communities do not benefit from the economies of scale associated with large-scale energy production.
2. Due to this, capacity that is low in investment cost but high in operational cost, such as diesel generation, is quite typical
3. Remote communities are often not connected to the grid because of logistical constraints, i.e. losses associated with the transport of electricity of long distances, or the physical difficulties of running high voltage cabling through difficult terrain (oceans, mountains, national parks, etc.) These physical obstacles also pose further financial burden upon consumers, as they are forced to bear the additional logistics costs of fuel transport as well.

Each of these problems creates an additional financial burden on the owners and operators of remote grids. This burden is reflected in the increased price of electricity produced. In cases where this is passed on to the consumer, this burden eats away at the purchasing power of the individual or business, slowing economic growth. Often, this increased cost is borne by the government in terms of energy subsidies, artificially deflating energy prices, draining government resources and leading to foregone opportunity costs (Bacon, Ley, & Kojima, 2010, p. 37). This solution, while alleviating the burden to the consumer, is not a sustainable solution. This paper argues that intelligent investment in domestic energy and material potentials, rather than unnecessary spending in the form of energy subsidies, creates a more sustainable long-term solution[1].

Defined by geographic and often political boundaries, islands and island nations are inherently remote communities. With very few exceptions (e.g. 20th century Bahrain), Islands are forced to import the majority of their energy vis-à-vis diesel or bunker fuel. Depending on their proximity to the mainland, islands may or may not be connected to a regional or national grid. Some islands like Vancouver Island, in British Columbia, Canada, are connected to the national grid via submarine cabling. Others, and many of those in the developing world like the Maldives or as in

[1] i.e. the money that is spent subsidizing energy (financial flows outside of the region) could be put to work instead by investing in regional energy management, assisting the uptake of sustainable energy solutions.

the example posited in this paper, Marinduque, Philippines, are forced to supply electricity via in-situ generation, leading to cost increases as described above.

Islands are also at the forefront in the battle against climate change. Low lying islands are at the greatest risk from rises in sea level and other changes to ocean ecosystems (e.g. acidity changes, coral bleaching, and marine habitat destruction). As such, they have the added incentive to minimize their personal impact in the creation of greenhouse gases (GHG). With a greater economic and environmental will, island nations that adopt MFM and Circular Economy concepts with regards to sustainable energy production, have the potential to take a leadership role in the sustainable energy revolution, providing concrete examples of the positive effects associated with the paradigm shift in energy production towards regenerative energy solutions. Marinduque, Philippines, is a typical example of a remote island community as defined above. This paper intends to show that the overall added value created by the provision of electricity from regenerative sources is not only beneficial environmentally, but provides long term economic and social sustainability as well.

Energy Security

The International Energy Agency (IEA) describes energy security as the continuous availability of energy that is both affordable and environmentally responsible (International Energy Agency, 2012). The IEA distinguishes between long and short-term energy security. According to the IEA, Long-term energy security involves the investment in economically and environmentally sound energy supply to meet energy requirements in a dynamic global environment (International Energy Agency, 2012). As such, providing energy security in the long-term also emphasizes the need to diversify away from fossil energy resources that pose environmental issues and additionally show a continual upward trend in price, reflecting both the growth in demand and the finitude of the resource itself.

Alternatively, short-term energy security involves the reinforcement of energy supply infrastructure in order to provide a prompt and adequate response to sudden changes in supply and demand (International Energy Agency, 2012). In instances when the supply of energy is interrupted, energy supply infrastructure must be able to react to the disruption and continue to provide electricity. In the case of remote communities, the reliance on fossil fuels from sources outside of their system puts them at particular risk. Disruptions to energy supply can be caused by numerous challenges, including extreme weather, infrastructure malfunctions, or cost increases outside of acceptable limits. This insecurity may force remote communities to stockpile contingency energy reserves, leading to further increases in energy price to the end user.

Energy security and thus, sustainability, in the short and long-term, requires diversification of energy supply away from foreign energy sources by maximizing the use of domestically available resources. Energy security not only helps to avoid the economic impacts caused by the disruption of supply, but also encourages local investment and reinvestment, creating growth within the region. By maximizing the use of material and energy flows within a region, financial flows are kept within the region itself.

In this paper, the Marinduque example helps to exemplify the benefits of investment in sustainable energy supply, providing examples that demonstrate both the short and long-term effects of implementing the circular economy model through investment and ultimately reinvestment in the island and its energy infrastructure.

Circular Economy

The Institute for International Material Flow Management (IfaS) recognizes that, "A Circular Economy emphasizes energy and materials efficiency strategies, while activating the regional growth potentials and creating regional added-value." (IfaS, 2012). There are many definitions of circular economies however this paper enhances the definition by adding that circular economies encourage the use, re-use, maximization and optimization of material, energy and financial flows within the boundaries of a defined system.

Traditional, 'linear economy' models rely on the import of energy and materials into the system while continuously exporting its financial capital to pay for them (Figure 1). This model often ignores regional material and energy potentials while diluting the purchasing power of the system in a continuous and structured cycle of debt and payment.

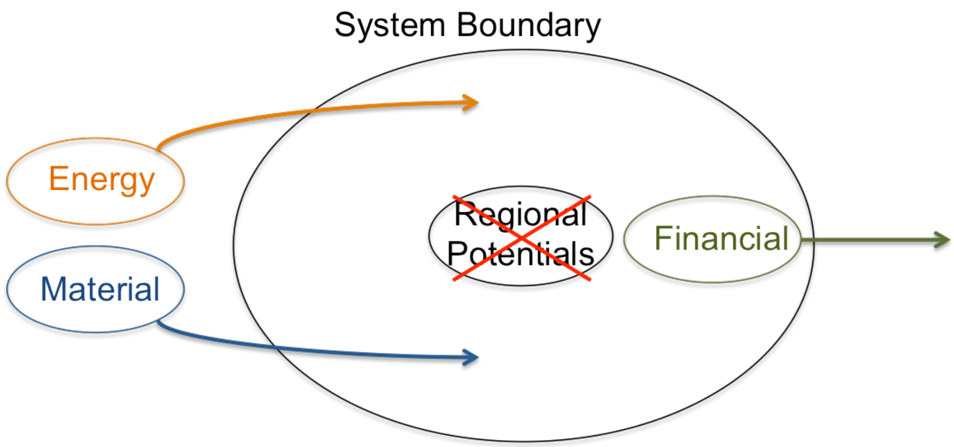

Figure 1: Linear Economy Diagram (IfaS, 2012)

A traditional linear economy imports energy and materials while exporting its financial capital to pay for these services. In the linear model, regional energy and material potentials are left untapped and the financial ability to do so steadily erodes over time, creating a cycle of systemic poverty within the region.

A circular economy model on the other hand is designed to maximize the use of regional material and energy potentials, creating a cycle of investment and re-investment on a regional level.

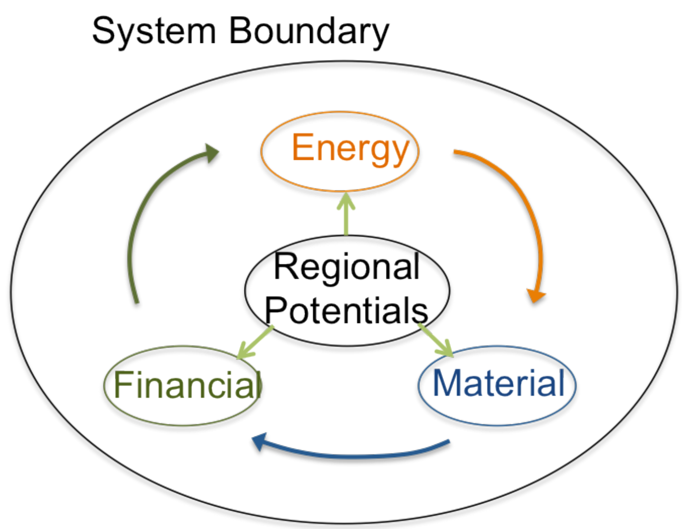

Figure 2: Circular Economy Diagram (IfaS, 2012)

By maximizing the use of domestic potentials, circular economies, as represented in Figure 2, help to create sustainable growth within a region, enhancing domestic economic wellbeing, increasing purchasing power, and helping to break a cycle of debt and payment (systemic poverty).

In the example posited in the second half of this paper, Marinduque currently imports 100% of its energy in the form of diesel fuel. Electricity is generated on the island at a 10MW diesel electricity generation station owned and operated by Manila Electric Railroad and Light Company (MARALCO). Electricity fees on the island are exorbitant (0.27 EUR/kWh) and the supply of electricity is intermittent. Marinduque itself has multiple untapped renewable energy potentials, however the current linear economic model traps it in the current cycle of debt and payment, exporting its financial capital, eroding the purchasing power of the government and people, all the while receiving little in terms of stable electricity supply, thus slowing growth in the region. This paper intends to show that the regional added value created through investment in regenerative energy systems and the creation of circular economies has both positive long-term and short-term implications for the energy security of Marinduque. Activating regional potentials on Marinduque has the potential to create energy security while providing the backbone for long-term growth in the region, helping to break the cycle of systemic poverty.

Regional Added Value

Regional Added Value (RAV) is defined in economic terms as the total revenue created by all factors of production within a defined system, less the cost of inputs into the system (CIPRA, 2008). In traditional terms, the regional value added refers to the economic benefit that the region adds to a product through processing, manufacturing or other means of production. RAV on the other hand emphasizes the creation of economic, social and environmental value based on the maximization of domestic potentials as highlighted in the circular economy concept discussed in the previous section.

For example, Japan is a country limited in traditional energy sources and must import coal, oil, gas and uranium to meet their primary energy demand. While dependent on the import of fossil energy, Japanese industry has developed traditional economic value added solutions. Japan has developed a large petrochemical industry, importing crude oil (mostly from the Middle East), refining it into lighter fuels for vehicles and energy production, as well as petroleum based chemicals for sale and use in other industries. Japan imports a raw material for price (x), processes it at cost (y), and sells the value added final product for price (z). In this case the regional value added is represented in the following formula:

$$\text{Economic Value Added} = z - (x + y)$$

As the worlds third largest importer of crude oil (Energy Information Administration, 2012) Japan has created an economic value added process through the refining of petroleum products and has spurred other strategic domestic industries and interests. While of key strategic interest to the Japanese economy, the traditional economic value added approach has neglected key domestic energy and material potentials such as geothermal power production, agricultural biomass waste-to-energy or even thermal energy capture from their extensive waste incineration system. Under a RAV scenario, maximizing the use of domestic energy sources, Japan could instead reduce its dependence on foreign energy sources through substitution, decreasing its export of financial capital and increasing both short term and long-term energy security.

Similarly, Marinduque is also dependent on fossil energy imports in the form of diesel fuel. In the case of Marinduque however, no domestic economic value is added.[2] Marinduque currently abides by a linear economic model, in a system of debt and payment, which only helps to reinforce structural poverty on the island. This paper argues that by maximizing the use of regionally available material and energy flows, using the concepts put forward in Material Flow Management (MFM), Marinduque has the opportunity to create investment opportunities, building a regional circular economic system, increasing energy security, and creating economic, social and environmental RAV.

Material Flow Management (MFM)

In 1994 the German Bundestag Enquete Commission defined Material Flow Management (MFM) as the, "management of material flows by the involved stakeholders and refers to the goal oriented, responsible, integrated and efficient controlling of material systems with the objectives arising from both the economic and ecological sector and with the inclusion of social aspects." (Helling, n.d., p. 25) Material Flow Management is a tool that is used to identify and activate material and energy potentials within a region that keeps in mind the triple bottom line of economic, environmental, and social welfare in the region.

[2] The case could be made that electricity from fossil fuel imports supports the tourism industry, however this paper recognizes the supply of electricity as essential to provide quality of life and standard of living to both the inhabitants and the island's guests. As such, high prices and intermittent supply of diesel (and thus electricity) actually contributes to economic retardation and a decrease in living standards according to the circular economy concept, as economic flows are exported from the island rather than invested in domestic energy potentials.

While in MFM there is no one-size-fits-all solution, it is instead a tool that is used to identify regional material and energy potentials in the goal of creating circular economic systems, increasing energy security, stimulating economic growth and creating RAV according to the triple bottom line of sustainability.

Potentials will inevitably differ from region to region and as such, innovative approaches must be taken to maximize their sustainable usage. In the case of Marinduque, Philippines, coconut and rice agriculture are the largest occupations on the island, accounting for the majority of jobs and income. Residuals from these products are typically left to decompose or are burnt in open-air piles. Biomass residual waste on Marinduque accounts for a large, versatile, and untapped source of energy. Section two of this paper applies the principles of MFM, identifying the economic, technical and energetic potential of these energy sources, in an attempt to show the short and long term benefits from increased energy security. While Part II of this paper focuses on the implementation of biomass-to-energy systems on Marinduque, other regenerative energy solutions such as wind and solar photovoltaics are also available and should not be ignored but are beyond the scope of this paper. Reinvestment opportunities with financial gains from the project described in this paper can contribute to greater levels of regional added value and the development of a 100% energy secure island.

Economic Development and Energy Security

Access to electricity is a fundamental requirement not only for economic growth but also for quality of life. Electricity is used to provide basic necessities such as lighting, cooling, refrigeration, pumping and cleaning water and many other services that the developed world takes for granted. Electricity services, "contribute to social development through education and public health, and help meet the basic human need for food and shelter" (International Energy Agency, 2004, p. 330). In their 2002 survey, the United Nations Development Programme (UNDP) and the International Energy Agency (IEA) show the correlation between Human Development Index (HDI) rating and electricity consumption per capita, per year:

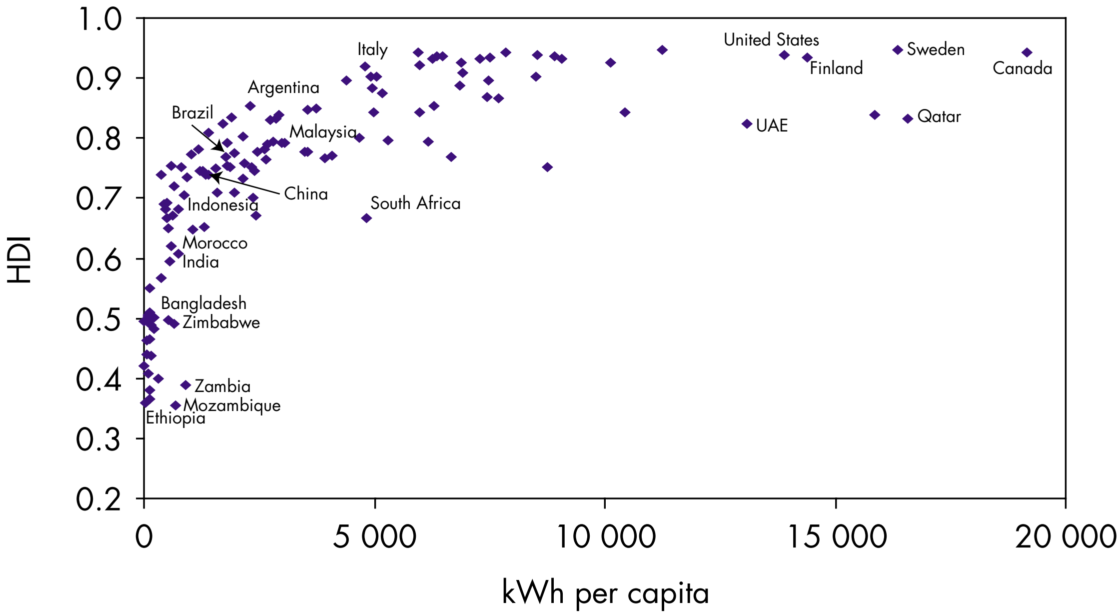

Figure 3: UNDP/IEA HDI ranking versus electricity consumption (kWh/capita/year) (International Energy Agency, 2004, p. 339)

The results demonstrate two important conclusions: Firstly, the increase in electricity consumption, both a result of access to electricity and availability of affordable electricity prices, create a direct increase in HDI ratings. Secondly, the results are non-linear, indicating that small increases in the availability of electricity create large increases in human development (International Energy Agency, 2004, p. 338).

Electricity is fundamental to human development, and as such, increased access to electricity leads to a higher standard of living. However this increased access to electricity also creates a virtuous cycle of human development and economic development. As basic needs are better met, human capital is freed to work in greater value added industries. The availability of electricity also adds to a county's ability to run the capital and equipment required to add economic value. The use of electricity sourced from sustainable, regional energy potentials helps to encourage the development of human and economic potentials, reinforcing circular economies, and breaking a cycle of systemic poverty.

Conclusions Drawn

Energy security for the sustainable management of remote communities and islands requires a dynamic approach to the handling of regional financial, material and energy flows and must encompass all concepts as set forth in Part I of this paper.

Part II of this paper uses the principals of MFM to identify and activate regional energy potentials with the goal of creating a circular economy system. Part II is designed to demonstrate that the activation of regional potentials helps to create both short-term and long-term energy security, creating a virtuous cycle of human development and economic growth through the sustainable supply of energy, helping to eliminate systemic poverty.

While there is no one-size-fits-all solution, the MFM approach to the sustainable management of remote communities and islands inherently begins with the identification of regional energy potentials. These potentials must be evaluated for their energetic, technical and socially acceptable potential and compared on a case-by-case basis against current, business-as-usual practices. The goal of the field research conducted in 2011 on the island of Marinduque, Philippines, is to highlight the economically and technically feasible energy potentials on the island and as well as the application of the results to a sustainable project design, keeping in line with the concepts outlined in Part I of this paper.

In the second part of this paper, the case for investing in regenerative energy systems on Marinduque is made using a comparison between the business-as-usual (BAU) scenario and the potential biomass-to-energy scenario. The comparison is designed to highlight both the short-term and long-term economic, environmental and social value in investing in regenerative energy systems in line with the key concepts of the sustainable management of remote communities and islands as outline in Part I of this paper

Part II: Marinduque, Philippines

Goals

The goal of part II of this paper is to prove that by using the locally available biomass, fossil energy consumption can be significantly offset, freeing up capital for investment and reinvestment into the local economy, creating and reinforcing the circular economy principles. Part II of this paper demonstrates that the activation of regional energy potentials helps to create energy security, reinforcing a virtuous cycle of social development and economic growth. The following section briefly outlines the approach taken in Part II of this paper

Methodology

1. Identification of regional potentials
2. Evaluation of potentials
    a. Energetic availability
    b. Technical availability
3. Management of Material Flows through Sustainable Project Design
4. Economic Evaluation
5. Regional Added Value Perspective
    a. Economic
    b. Environmental
    c. Social
    d. Future Potentials
6. Evaluation and Conclusions Drawn

Field research and results

Research Methodology

Field research is a vital aspect of Material Flow Management. By better understanding the local characteristics, energy and material flows that occur within the system boundaries, solutions can be optimized to suit the local conditions. Because regenerative energies are not one-size-fits-all solutions, specific local knowledge is needed to optimize the project for its financial viability, social acceptability and long-term sustainability.

The goal of the field research was to establish the biomass energy potential of the island. The total biomass energy potential presented in this report includes the biomass that is both available for use, the technologically available fraction and the final energy production potential based on reasonable operational efficiencies.

Research included on-site analysis with the help of government officials, town engineers, barangay captains, and farmers. Analysis of total biomass figures was complemented by on-site investigation to understand the specific local characteristics of the various material and energy flows in question. By understanding these individual characteristics, the Santa Cruz project was designed to maximize these regional potentials by creating a circular economic vision. The results of the field research and suggestions for project development are highlighted below.

Marinduque: Current Situation

Power Supply and Demand

Marinduque Island, its municipalities and barangay's, are all provided with electricity from a central, diesel power generation unit in Boac, owned and operated by Manila Rail Electric and Light Company (MARELCO). This floating power facility has an electricity rating of 10MW.

Currently, a combination of logistic and financial difficulties prevents the adequate supply of diesel fuel from reaching Boac. Current diesel fuel availability limits power generation to an estimated $4.5MW_{elec}$.

The total electricity demand of the island is estimated at $10MW_{elec}$ and under previous operating characteristics, the supply from the MARELCO Boac unit provided sufficient energy for the island's current needs. However under the current reduced capacity, electricity shortages are a daily event[3].

Consequences of the Current Power Supply Situation

As a consequence of this, the six municipalities on Marinduque are subject to 'brown-outs', where electricity is shut off to two of the six municipalities every evening during peak hours (18:00 – 22:00), on a rotating basis. With no electricity, the people of Marinduque are forced to either own and operate independent diesel generators or end the working day as the sun goes down. Without electricity, services such as air-conditioning, television, internet, street lighting, and all home electricity uses are suspended. Not only does this effect quality of life on the island, but also negatively affects the tourism industry, creating further financial difficulties for the people of Marinduque.

Correlation of Energy Supply and Demand

The relationship between the supply and demand of electricity will inevitably vary with different geographic and socio-economic conditions. In economically developed nations, where consumers can generally afford to pay for energy services, the supply of electricity generally reacts to

[3] Please see: 'Correlation of Energy Supply and Demand' section for further information

increases in demand. In developed nations, electric utilities operate with increasing competitiveness and are able to either internally raise capital or access finance to expand supply to meet demand with affordable energy services (Krishnaswamy & Stuggins, 2007, p. 3).

While the supply of electricity normally mirrors the demand of the consumer, for remote communities and islands, especially those in the developing world, this is not always the case. In remote communities like Marinduque, the cost of supplying energy to the island exceeds the ability of its inhabitants to pay for it. The World Bank Group explains that, "In the least developed and low-income economies, access to electricity is limited, and the low income level of consumers often does not enable the utilities to cover fully the cost of supply, let alone generating surpluses to finance system expansion" (Krishnaswamy & Stuggins, 2007, p. 3). So while demand for energy in remote communities may higher than supply, the cost of supplying energy artificially decreases demand, further decreasing the utility's competitiveness and ability to finance affordable expansion. This in turn prevents adequate access to electricity, decreasing growth in consumption by inhibiting economic growth.

While not met under current circumstances, the demand for electricity on Marinduque may actually exceed the maximum supply potential of the MARELCO diesel generation unit at Boac. As such, expansion of affordable energy services as posited in this paper could theoretically lead to a growth in demand exceeding the current supply capacity. While mapping this growth and the effect of affordable energy services on demand is not within the scope of this paper, it is important to keep in mind that increased energy security on Marinduque may potentially increase the overall demand for energy on the island.

Research Findings

Biomass Energy Resources

The primary occupation on Marinduque is agriculture. The agricultural profile of the island is split primarily between wet rice cultivation and coconut plantations. The following sections outline the cultivation practices, total harvest and available biomass residues.

Biomass From Rice Cultivation

Rice is cultivated on 5,284ha. of land on Marinduque. In one year there are two growing seasons for a total annual harvest of 29,526t. For this study it is surmised that the harvest is split evenly between the two growing seasons for a bi-annual harvest of 14,763t/season.

Currently, biomass residues from rice production are under utilized. Assuming standardized ratios of husk&straw : grain (70:30)[4] we can accurately estimate the total quantity of non-edible

[4] Rice residues to husk relationships vary by rice strain and location. The ratio used in this report is an averaged figure taken from various studies on Residue to Husk Ratios (RHR) throughout Southeast Asia. Ratios vary from 67:33 (Papong, Yuvaniyama, & Lohsomboon), 62:38 (Japan Institute of Energy, n.d.) and up to 88:12 (Lim, Manan, & Hashim, 2012). This paper assumes 70:30 is a reasonable estimate, neither too high nor too low.

biomass that is produced during cultivation. Using this ratio, the annual production volume of 29,526t/year of grain yields an estimated 50,195t of dry residues a year or 25,098t/season. Furthermore, assuming that a reasonable 50% of this biomass is recoverable for use, we can estimate that there is a total of 25,098t/year and 12,549t/season of combustible residue available.

Currently the agricultural residues from rice cultivation are either burned on the field, in the case of rice straw, or left for natural decomposition at the rice mill, for the husk. Because these by-products are currently not utilized there is both an untapped energy and a GHG abatement potential.

Biomass from Coconut Plantations

Coconut farming accounts for the largest agricultural land use on Marinduque. At 35,448 ha of land, coconut plantations outpace land used for rice cultivation. Coconut is farmed on Marinduque to produce ‘copra’, the smoke-dried, white meat of the coconut. Copra is a major export from Marinduque, purchased by coconut-oil producers and sold to end consumers and tertiary producers.

Because copra production exhibits degrees of annual variation, this study uses the lowest available figure in the last 10 years. In 2009, Marinduque produced approximately 2,868t of processed copra from 9,561t of raw coconut. From the total raw biomass weight of the coconut there is a standard ratio of (33.3):(15):(21.7):(30) relating the husk : shell : water : meat.[5] From this relationship it is estimated that during years of lowest production there is 3,184t of coconut husk available.

Coconut husks are separated from the shell and meat by hand, using traditional tools, on site at the plantations. The meat is then placed over an open-air kiln and cured with smoke to prevent rot. The husks from the coconuts are used as fuel for the kiln. On average, one third of the husks from the harvest are used to cure the coconuts in the kiln, the rest are left in piles to decompose naturally and can be seen scattered around the island.

Whole Island Biomass Energy Potentials

Energy Potential from Rice Husk and Straw

From the total available biomass we can calculate the energy potential of these biomass energy feedstocks. Rice straw and husk has a lower heating value (LHV) of 13.4 MJ/kg or 0.0134 TJ/t. From the total available residues on Marinduque, the energy potential of rice cultivation residues is estimated at 336 TJ/year or approximately 93 GWh/year.

$$25{,}098 \text{ t/year} \times 0.0134 \text{ TJ/t} = 336 \text{ TJ/year}$$

[5] Coconut residue to meat ratios were gleaned from interviews with local farmers and corroborated through online research. While water and meat content may vary due to climactic conditions and the age of the fruit bearing tree, it is generally assumed that 1/3 of the coconut is comprised of husk (Smith, Ha, Cuong, & Dong, 2009 p.21) and (Raghavan, 2012 p.1). For more precise project planning, this paper reccomends a sample (1000-5000 nuts) should be taken from Marinduque and broken down into their individual components to arrive on average ratios specific to Marinduquenian coconut agriculture.

$$336 \text{ TJ/year} \ / \ 3.6 \text{ TJ/GWh} = 93 \text{ GWh/year}$$

Energy Potential from Coconut Husk

Coconut husk has an LHV of 16.7 MJ/kg or 0.0167 TJ/T. As such, the total available energy supply from coconut husks on Marinduque is equal to 52 TJ/year or 15 GWh/year.

$$3{,}184 \ t_{husk}\text{/year} \times 0.0167 \text{ TJ/t} = 52 \text{ TJ/year}$$

$$52 \text{ TJ/year} \ / \ 3.6 \text{ TJ/GWh} = 15 \text{ GWh/year}$$

The total combined energy potential of rice husk, rice straw and coconut husks is equal to 159 TJ/year or 108 GWh/year.

Technical Potential: Electricity Production

From this total energy potential, only part of this energy is technologically recoverable. To convert the chemical energy stored in the biomass to usable electrical and thermal energy, the biomass must be burned in a combustion unit. Various designs exist with varying degrees of efficiency and technical complexity but for this study we assume a reasonable boiler efficiency of 80%[6] and an electrical efficiency of 40% from the generator. For the sake of project design later on we also assume that a heat and electricity co-generation unit is used.

With a total available biomass energy potential of 159 TJ/year or 108 GWh/year combusted in a reactor with a boiler efficiency of 80%, 127.2 TJ/year or 86.4 GWh/year of thermal energy can be produced.

$$159 \text{ TJ/year} \times 0.80 = 127.2 \text{ TJ/year}$$

$$108 \text{ GWh/year} \times 0.80 = 86.4 \text{ GWh}_{Thermal}\text{/year}$$

Using an electrical generator with an efficiency rating of 40%, we can assume that the energy provided by the steam from the boiler will provide 50.88 TJ/year or 34.56 $\text{GWh}_{Electric}$/year.

$$127.2 \text{ TJ/year} \times 0.40 = 50.88 \text{ TJ/year}$$

$$86.4 \text{ GWh/year} \times 0.40 = 34.56 \text{ GWh}_{Electric}\text{/year}$$

Assuming further that the machine is operated for 7,800 hours/year due to downtime for routine maintenance, we can estimate that the total electricity generation rating for a single combustion facility would need to be 4.431 $\text{MW}_{Electric}$.

$$34.56 \text{ GWh/year} \times 1000 = 34{,}560 \text{ MWh/year}$$

$$34{,}560 \text{ MWh/year} \ / \ 7800 \text{ hours/year} = 4.431 \text{ MW}_{Electric}$$

[6] Thermal efficiencies will be dependent on final choice of supplier. An empirical study of biomass fired boilers showed average thermal efficiencies above 80% (IBR Steam Boilers; 86 +/- 2% (Industrial Products Finder, 2012), Baxi; 94.1% (Baxi, 2012), Thermax; 80% (Thermax, 2012). This study uses a low range thermal efficiency of 80% to highlight reasonable thermal output expectations.

Thus, the total technical energy potential of biomass combustion on Marinduque Island is equal to approximately one half of the current installed diesel generation capacity. This figure represents the total technically available biomass energy potential on the island of Marinduque. The next section addresses specific design parameters for project implementation and includes further usable biomass and electrical losses associated with the processing and storage of biomass as well as reasonable estimations for internal electricity uses and distribution losses. After deriving the final electrical output from the biomass co-generation system an estimate for annual revenue can be assumed and thus the economic added value of the project derived.

Project Development

While the long-term energy strategy of Marinduque is the sustainable development of all regional energy potentials it is important to develop an implementation strategy on a project-by-project basis. By developing biomass-to-energy systems on Marinduque on a case-by-case basis, specific technical and energetic potentials can be broken down and better understood. Expanding the small-scale analysis to an island wide system will therefore provide a more accurate energetic and financial overview of island wide implementation.

The following section makes the case for Marinduque's first biomass-to-energy cogeneration system centered in the municipality of Santa-Cruz.

Development of the Santa Cruz Biomass-to-Energy Cogeneration Project

Santa Cruz is one of the six municipalities of Marinduque, located on the North East of the island. Like all the municipalities, a large part of land use is used for rice and coconut farming. Calculated in the same manner as the previous section, there are 9,034t/year of rice related agricultural residues and 880 T/year of coconut husk available for cogeneration.

Biomass Energy and Installed Capacity

The total available chemical energy from the rice residues is estimated at 121.05 TJ/year or 34 GWh/year. Assuming the same boiler efficiency (80%) and electrical efficiency (40%) from the generator, rice residues have the potential to produce 10,760 MWh/year from an installed capacity of 1.38 $MW_{Electric}$.

$$9{,}034 \text{ T/year} \times 0.0134 \text{ TJ/T} = 121.05 \text{ TJ/year}$$

$$121.05 \text{ TJ/year} \,/\, 3.6 \text{ TJ/GWh} = 34 \text{ GWh/year}$$

$$34 \text{ GWh/year} \times 0.80_{Eff.Boiler} = 26{,}900 \text{ MWh/year}$$

$$26{,}900 \text{ MWh/year} \times 0.40_{Eff.Electric} = 10{,}760 \text{ MWh/year}$$

$$10{,}760 \text{ MWh/year} \ / \ 7800 \text{ hours/year} = 1.38 \text{ MW}_{Electric}$$

The total available chemical energy from the coconut husk is estimated at 14.7 TJ/year or 4 GWh/year. Assuming the same boiler efficiency and electrical efficiency from the generator, coconut husks have the potential to produce 1,307 MWh/year from an installed capacity of 170 $kW_{Electric}$.

$$880 \text{ t/year} \times 0.0167 \text{ TJ/t} = 14.7 \text{ TJ/year}$$

$$14.7 \text{ TJ/year} \ / \ 3.6 \text{ TJ/GWh} = 4 \text{ GWh/year}$$

$$4 \text{ GWh/year} \times 0.80_{Eff.Boiler} = 3{,}267 \text{ MWh/year}$$

$$3{,}267 \text{ MWh/year} \times 0.40_{Eff.Electric} = 1{,}307 \text{ MWh/year}$$

$$1{,}307 \text{ MWh/year} \ / \ 7800 \text{ hours/year} = 170 \text{ kW}_{Electric}$$

The total combined installed capacity for the project would be 1.55 $MW_{Electric}$ capable of producing approximately 12,067 MWh of electricity per year.

Operating Losses

Assuming the optimal scenario as described in the previous sections, where 50% of the total biomass residues produced are available for use in power generation, a boiler efficiency of 80% and an electrical efficiency of 40%, a 1.55 $MW_{Electric}$ generator operating for 7,800 hours per year has the potential to produce 12,067 MW of electricity for sale each year. This number represents the technical potential of electricity production from biomass residues in the municipality of Santa Cruz. However, closer evaluation of the project requirements reveals further energetic losses that must be accounted for.

Biomass Shredder and Pelletizer

Raw biomass, as either coconut husk or rice husk and straw requires further processing to maximize its combustion efficiency and allow it to be stored for extended periods of time. Biomass is most effectively stored in a pelletized form. Biomass pellets have three distinct advantages: One, the biomass is protected against rot and natural decomposition, especially important in the tropic environment of Marinduque. Two, the surface area of the fuel is dramatically increased and standardized; increasing combustion efficiency and fuel feed predictability. Three, because pellets are formed through compression of shredded biomass, the energy content of the fuel is increased (in terms of energy per unit area) and standardized to ensure consistent energy output at a specific feed rate. It is generally accepted that the system design advantages of using standardized fuel outweigh the costs associated with using raw, unprocessed biomass in the combustion unit. Because of these advantages, extra investment into a biomass-pelletizing unit is required.

Biomass Shredding Machine

The first step in the biomass processing is shredding. Coconut husks, rice straw and even the fine rice husks must be shredded into a powder for before being fed into the pelletizer. This can be achieved by employing a simple biomass shredder, like in the example shown below:

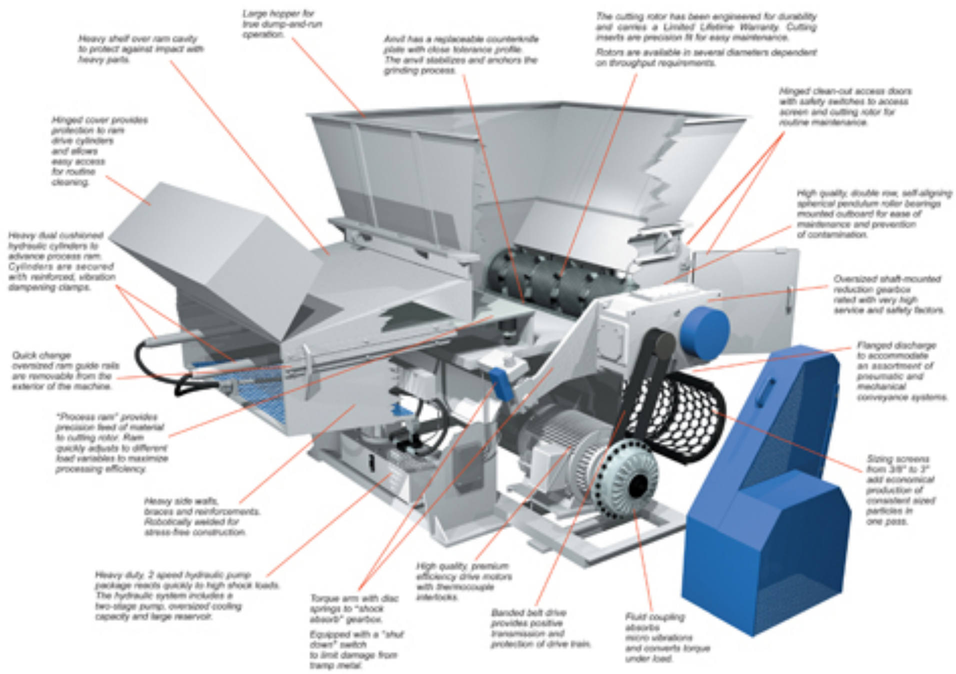

Figure 4: Example Biomass Shredding Machine - Vecoplan (Vecoplan, 2012)

The rice and coconut residues are fed into the machine in their raw form, are shredded by the cutting rotors and deposited as a fine powder as shown below:

Figure 5: Example - Shredded Coconut Husks Vecoplan (Vecoplan, 2012)

Biomass Pelletizing Machine

The shredded biomass is then fed into a pelletizing machine like the one shown below:

Figure 6: Example: Electrical Biomass Pelletizer - Anyang GEMCO (Anyang Gemco Energy Machinery Co. Ltd., 2012)

The biomass is compressed by a piston or screw drive (machine dependent) and extruded through a screen, shaping the final biomass pellets to the desired size.

Figure 7: Example: Coconut Husk Pellets (Wandamachine, 2012)

During the process of collection, shredding, pelletizing and the storage of pellets for combustion there are inevitable losses of usable biomass (e.g. losses as fine dust). While material losses are situational and dependent on multiple factors including handling and storage, this paper estimates that roughly 10% of total available biomass will be lost during the processing phase.

Electrical Losses

From the total electrical production there will be inevitable losses in the form of internal consumption, both for the operation of processing machinery as well as for onsite uses such as lighting and security. While operating losses (outside of generator efficiency) will depend on the choice of machinery and efficiencies of the onsite electrical equipment, this paper assumes operational losses of 15% of total saleable electricity through internal consumption requirements.

For a final financial calculation, a precise calculation of actual internal energy use is required and may vary from the amount used in this feasibility study depending on the specific technical equipment used.

Furthermore, as electricity is stepped up to medium or high voltage and distributed to the existing grid, transportation efficiency losses must also be calculated. This paper estimates that distribution losses of 5% are to be reasonably expected.[7]

Diagram of Total Material and Electrical Losses

The following is a flow diagram outlining the flow of energy and material within the system, highlighting both material and electrical losses as described above.

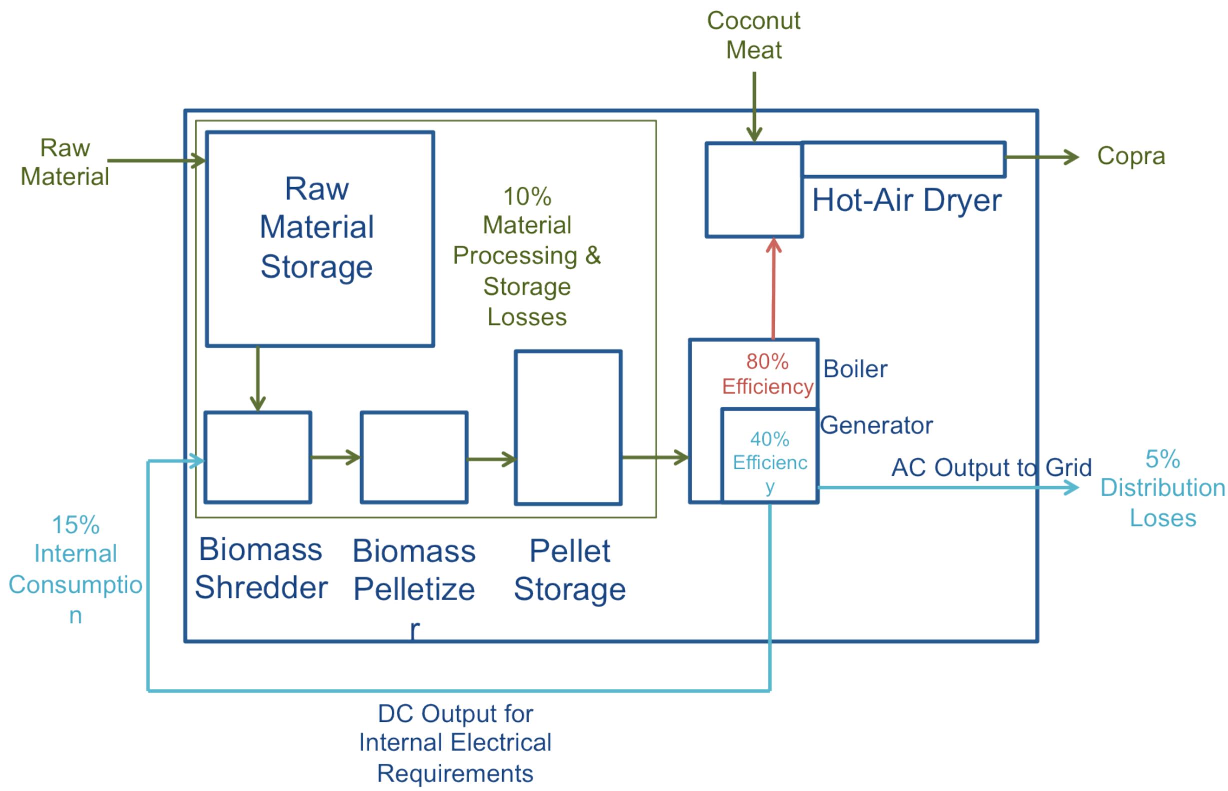

Figure 8: Material and Energy Flow Chart - Material and Electrical Losses In Proposed Project Design

[7] Distribution losses are related to: 1. The electrical power rating of the plant (P), 2. The voltage at which the electricity is transported (V), 3. The resistance of the power cabling (R) and 4. The current transmitted (I), by the formula I^2 R or (P/V)^2 R (Physics Forums, 2008). As all information relative to this calculation were not available, an exact calculation of distribution losses for this project was not possible. The 5% distribution losses estimated in this paper is based on a literature review and taken from the US EPA claiming an average distribution loss factor of 7% (U.S. Environmental Protection Agency, 2007) and lessened to account for differences in average distance of distribution (from generation to consumer).

Summation of Project Energy and Material Flows

Material Flow Synopsis		
Total Annual Availability of Raw Biomass from Coconut Husks, Rice Husks and Rice Straw	t/year	9,914
Total Fuel Availability After Internal Losses from Machine Shredding and Pelletizing (10%)	t/year	8,923
Coconut Meat for Hot Air Drying	t/year	793
Copra Produced From Hot Air Drying[8]	t/year	452

Energy Flow Synopsis		
Energy Potential of Processed Biomass Pellets	MWh/year	33,939
Electrical Output After Boiler and Generator Efficiency Losses	MWh/year	10,860
Salable Electricity (After Distribution Losses)	kWh/year	8,769,718

Co-Generation Design Optimized for Pelletized Biomass Scenario		
Size of Biomass Pellet Fired Co-Generation Unit	MW	1.39

[8] Coconut meat must be dried for preservation and transportation to tertiary producers. On Average, coconut meat has a moisture content of 50% (de Leon & Delores, 2005, p. 16) and must be dried to 7% or below. As such, the final weight of dried copra is roughly 43% lower than that of the raw coconut meat.

After evaluating the project specific information including the processing of raw biomass into pellets, the internal use of electricity required for the operation of additional machinery as well as the distribution losses of electricity, this paper concludes that a cogeneration unit of 1.39 MW, operating for 7800 hours per year is required to utilize the 9,914t of raw biomass, creating 8,769 MWh of salable electricity per year. The additional use of the thermal energy from cogeneration to process coconut meat into copra will be covered in the added value section to follow. The next section evaluates the economic value added associated with the Santa Cruz Biomass Co-Generation project.

Economic Value Added

Financial Characteristics and Evaluation

This section provides a financial feasibility study in order to highlight the long term benefit of switching from a fossil fuel driven linear economic model to a regenerative energy driven circular economic model. In order to provide this, a number of assumptions regarding system costs were used. While it is important to use reasonable assumptions during the feasibility study, actual figures may vary and as such, timely Requests for Quotation (RFQ) from appropriate suppliers must be used. The following outlines the financial assumptions used in this paper:

Capital Expenditure and Cost of Capital			
Capital Expenditure	EUR/kW	3000	Capital expenditure includes the cost of the cogeneration unit as well as facility costs including the housing structure, power electronics, construction and installation.
Debt : Equity Ratio	%:%	85 : 15	
Interest on Equity	%	15%	
Period on Equity	Years	5	
Interest on Debt	%	5%	An interest rate of 5% assumes a preferential loan from a domestic financial institute with development priorities. The Land Bank of the Philippines has indicated their interest and is a potential lender to Marinduque

			biomass-to-energy development. Project sensitivity to loan rates is addressed in the following sensitivity analysis.
Period on Debt	Years	8	
Maintenance Costs per year as a percentage of Investment	%	10%	The cost of spare parts, routine maintenance including the possible necessity of external support for troubleshooting

	Labor		
Operators	Persons Salary (EUR/year)	4 10,000	Assuming 8 hour shifts with time off requirements, 4 operators are required to manage the daily operational requirements including operation of co-generation equipment and biomass processing
Engineer	Persons Salary (EUR/year)	1 20,000	Routine maintenance of co-generation and biomass processing machinery requires skilled labor in the form of engineering support
Management	Persons Salary (EUR/year)	1 20,000	Management of the operators and engineer as well as accounting services requires management personnel

	Raw Material Costs		
Cost of Purchasing Raw Materials from	EUR/t	50	In order to incentivize farmers to provide the raw materials for energy production, they are to be paid 50 EUR per ton of raw material. As a part of

Farmers			the circular economic concept, the redistribution of financial gain from the project creates an additional domestic revenue stream by re-valuing agricultural wastes.

	Revenue		
Total Salable Electricity after Material and Energetic Losses	kWh/year	8,769,718	The amount of electricity that is available for sale after internal uses, distribution losses and losses from the processing of biomass are accounted for
Sale price of electricity	EUR/kWh	0.20	Currently electricity is sold to the end consumer at 15 Philippine Pesos (PHP) per kWh (0.27 EUR/kWh). Selling electricity from biomass cogeneration for 0.20 EUR/kWh is not only an incentive for implementation but creates a stable electricity price below BAU levels, helping to further maximize consumer spending power on all levels.

Applying the assumptions outlined above, taken over an estimated 20-year lifetime of the biomass co-generation facility, the project yields a Net Present Value (NPV) of 33,080 EUR at an Internal Rate of Return (IRR) of 8%.

The overall financial evaluation of the project under these circumstances yields a net benefit to the investor as well as providing an annual distributed income to the farmers of Santa Cruz of 495,706 EUR, paid for the raw biomass cogeneration feedstock. Furthermore, by reducing the price of electricity from biomass cogeneration from 0.27 EUR/kWh to 0.20 EUR/kWh the project yields a financial saving of 613,880 EUR/year distributed among all consumers in the municipality of Santa Cruz. The total combined financial benefit to the people of Santa Cruz is a combined total of 1,109,587 EUR/year. This figure represents the financial added value to the region through the activation of domestic energy potentials. The net saving at 1.1 million Euros per year in the municipality of Santa Cruz has been freed for re-investment in the community rather than being exported as payment for diesel fuel under the traditional linear economic model.[9] The following sensitivity analysis highlights some of the most important financial risk factors and provides further detail into the potential financial added value of the project.

Sensitivity Analysis

In order to highlight the importance of the different variables in the financial model, this paper presents a sensitivity analysis examining the possible outcomes caused by fluctuations in the assumptions made in the baseline scenario described above.

Baseline Scenario

The baseline scenario uses the cost assumptions stated above in an attempt to bring a maximum value to all stakeholders in the project. For investors, an NPV of 33,080 EUR over the 20-year project life and an IRR of 8% shows a reasonable return on investment. Where the investor is MARELCO, whose Marinduque projects are losing 415,000 EUR/year, the additional cash flow of 138,000 to 760,000 EUR/year (depending on debt and equity repayment periods) is certainly of benefit. Where the investor is the Marinduque government or the government with MARELCO in a PPP structure, both profitability in terms of ROI as well as regional financial added value are important. From this standpoint, this paper has tried to design the financial analysis to provide the maximum financial benefit to the people of Marinduque (by paying more to the farmers for raw materials and charging the minimum possible for electricity) while still creating a reasonable financial incentive for investors. As such, changes to the assumptions regarding external factors such as cost of capital and salable electricity, without corresponding adjustments in internal assumptions such as price of electricity or price paid to farmers will in turn cause project financial indicators to show negative results. Financial assumptions in the project are finely balanced to provide maximum value to all stakeholders. The sensitivity analysis shown below highlights these issues and shows changes in the value to different stakeholders based on changes to both external and internal project financial assumptions.

[9] Detailed NPV and IRR calculations are provided in **Annex 1** of this paper

	Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Worst Case	Best Case
Cost of Capital									
Equity									
Equity Period	5	5	5	5	5	5	5	5	5
Equity Rate	10%	10%	15%	10%	10%	15%	15%	15%	8%
Debt									
Debt Period	8	8	8	8	8	8	8	8	8
Debt Rate	5%	10%	5%	5%	5%	10%	10%	10%	4%
Investment									
EUR/kW	3000	3000	3000	3750	3000	3200	3300	3300	3000
EUR	4,177,051	4,177,051	4,177,051	5,221,313	4,177,051	4,455,521	4,594,756	4,594,756	4,177,051
Operating Costs									
O&M	10%	10%	10%	10%	10%	10%	10%	10%	10%
Personel	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000
Materials									
EUR/t	50	50	50	50	50	50	52	52	51
farmer revenue	495,706	495,706	495,706	495,706	495,706	495,706	515,534	515,534	505,620
Revenue									
EUR/kWh	0.2	0.2	0.2	0.2	0.2	0.2	0.22	0.18	0.19
Losses									
Internal Use	15%	15%	15%	15%	20%	10%	15%	20%	10%
Distribution	5%	5%	5%	5%	7%	5%	5%	7%	5%
Outcome									
Savings									
Electricity Costs	613,880	613,880	613,880	613,880	571,688	649,991	438,486	727,208	742,847
Farmer Revenue	495,706	495,706	495,706	495,706	495,706	495,706	515,534	515,534	505,620
Total Savings	1,109,586	1,109,586	1,109,586	1,109,586	1,067,394	1,145,697	954,020	1,242,742	1,248,467

	Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Worst Case	Best Case
NPV	33,080	(78,050)	2,195	(2,636,453)	(1,062,823)	107,657	223,283	(4,094,177)	71,325
IRR	8%	8%	8%	3%	5%	8%	8%	-2%	8%
ROI	1.58	1.54	1.57	0.45	1.00	1.64	1.70	(0.37)	1.60

Figure 9: Sensitivity Analysis - Summary of Baseline Financial Assumptions and Project Sensitivity to Changes

Sensitivity to External Changes

Cost of Capital Increases

Scenario 1 represents an increase in the cost of debt financing from the baseline scenario's assumed 5% to a cost of 10%, while Scenario 2 shows the effects of an increase in interest expected by lenders of equity finance from 10% to 15%. Interest rates on capital will ultimately reflect the motives and expectations of the different finance partners. For example, debt lending from the Land Bank of the Philippines as posited previously may require lower interest payments than a loan from an international organization.

While the change in NPV demonstrates that the project is sensitive to the cost of capital, the overall addition to project costs posed by a doubling of interest on debt, the ability of internal revenue mechanisms (such as slight increases in electricity costs, or decreases in payments made to farmers) to absorb these changes without disproportionately affecting regional stakeholders is within acceptable limits. As such, changes in the cost of capital (debt or equity) alone do not pose a significant threat to the overall financial viability of the project.

Increase in Investment Costs

Scenario 3 in the sensitivity analysis shows the effect of an increase in capital expenditure from 3000 EUR/kW to 3750 EUR/kW. An increase of 25% in the cost of capital without changes to project revenues yields a loss in terms of NPV of 2.6 million EUR over the project's estimated 20-year lifespan. The project is particularly sensitive to increases in capital expenditure as an increase in initial borrowing yields even greater annual costs of capital. While scenario 6 shows the ability to adjust internal revenue mechanisms to avoid project financial losses, higher investment costs will inevitably yield lower returns to farmers and electricity consumers. Because the impact of investment costs has a greater impact than cost of capital on the profitability of the project, special attention must be paid to purchasing and supplier selection for major project components. Keeping costs low in the planning and purchasing stages will yield a greater financial added value to all stakeholders.

Losses of Saleable Electricity

Scenario 4 represents changes in profitability due to an increased loss of salable electricity from both increased internal consumption and distribution losses. Losses of salable electricity directly erode project revenues and as such, all losses must be accurately accounted for in the design phase of the project.

Increases in distribution losses may be associated with a weak grid infrastructure and ageing or inefficient cabling on the island. These losses will also depend on the type of grid connection (Low, Mid or High Voltage) as transportation losses will increase at lower distribution voltage.

Increases in internal electricity consumption are equally disadvantageous and efforts to maximize internal efficiency are extremely important. For example, when selecting major components (i.e. Boiler, generator, biomass shredder, pelletizer, etc.) a comparison between system efficiency and price must be taken into account. Furthermore, loss in salable electricity also diminishes the RAV as shown in the savings loss to the end consumer.

While the selection of these components is important, it is outside of the scope of this feasibility study as it involves detailed information from suppliers that will be made available to the purchasing entity. Suffice to say that a balance must be struck between overall system costs and system efficiencies when choosing major components, as shown in Scenario 5.

Sensitivity to Internal Changes

Project Investment Costs v. Internal Efficiency

Scenario 5 describes a situation where the cost of debt and equity has increased above baseline assumptions. In this case however, the increase in capital expenditure from 3000 EUR/kW to 3200 EUR/kW is meant to mirror an investment decision into more efficient project components (theory: higher the investment cost, the greater quality of components). Even with disadvantageous loan conditions, the decision to purchase more expensive (over 300,000 EUR greater capital expenditure) components that operate at greater overall efficiency yields higher financial RAV and project profitability from the greater availability of salable electricity. Scenario 5 highlights the importance of supplier evaluation and selection keeping in mind that increases in investment may potentially yield better results even with an increase in perceived risk to investors.

Internal Revenue Mechanisms: Effect on Stakeholders

The choice to increase the price of salable electricity to compensate for external variables like capital expenditure and cost of capital has a detrimental effect on the RAV to electricity consumers as demonstrated in Scenario 6. Scenario 6 posits that the increase in electricity price from 0.20 EUR/kWh to 0.22 EUR/kWh decreases the total value added to electricity consumers by almost 200,000 EUR/year. Even accompanied by an increase in revenue to farmers by 2 EUR/t of raw biomass, the overall loss in financial value to the region over the baseline scenario is still great. As such, the use of internal revenue mechanisms (i.e. increase in electricity price) to compensate for increased project costs will inevitably diminish the overall financial added value to the region as a whole.

Best Case and Worst Case Scenarios

The best case and worst case scenarios used in the sensitivity analysis show the effect on both project profitability and RAV through the combination of changes made to internal and external financial assumptions.

In the worst-case scenario, capital expenditure, cost of capital and a decrease in salable electricity are adjusted as per scenarios 1 to 4. Furthermore, revenues are depleted in terms of price of electricity and costs for raw materials. The decrease in price from 0.20 EUR/kWh to 0.18 EUR/kWh could represent a ceiling price as demanded by MARELCO for the use of their transmission network, whereas the increase in price paid for raw materials may reflect the refusal of farmers to sell agricultural residues for the assumed price of 50 EUR/t in the baseline scenario. Both of these revenue disruptions highlight the need for cooperation among different stakeholders and the requirement of contractual obligations that secure prices within reasonable limits. As such, the worst-case scenario serves to highlight the importance of stakeholder management as posited in the definition of MFM.

The best-case scenario on the other hand assumes a decrease in interest on debt and equity combined with an increase in internal process efficiency. These advantages increase the availability of electricity for sale and correspondingly allow the decrease of sale price to 0.19 EUR/kWh as well as freeing up more capital to return to farmers for the purchase of raw biomass. Under the best-case scenario both RAV and project profitability are increased above the baseline scenario.

Identifying Investors

The implementation of biomass-to-energy systems on Marinduque represents a unique opportunity, however it also includes a paradigm shift away from the traditional linear economic model currently in place. As such, it is important to address the stakeholders that are affected by this change. While from the point of view of the people and government of Marinduque this project has the potential to yield significant added value as addressed in the previous and following sections, the current supplier of electricity, MARELCO, may potentially view the projects negatively. This however, should not necessarily be the case.

Currently MARELCO (the owners and operators of the Boac diesel electricity generation unit) operate at a significant financial loss due to increases in diesel fuel prices. The cost of electricity that can be borne by the end consumer is limited, in that significant price increases will be met by refusal of payment and reduction in consumption.

MARELCO reported in February of 2011 estimated electricity sales of 10,979,827 PP and costs of 12,999,932 PP for a total estimated net operating loss of 2,020,103 PP (or approximately 34,600 EUR). Operating at an average loss of 34,600 EUR/month (not including peak demands during tourist high season) this means a net operating loss of approximately 415,200 EUR/year.

As such, MARELCO should see biomass-to-energy projects as an investment opportunity. By investing in regional energy potentials and thus energy security on Marinduque, MARELCO has the potential to mitigate their losses they would accrue in the continuation of the current energy supply model. By investing in the energy future of Marinduque, MARELCO has the chance to earn a profit from the biomass-to-energy projects while decommissioning their failed Boac venture and thus mitigating future financial losses. By investing jointly with the various municipalities in a Public Private Partnership (PPP) scheme, regenerative energy systems can benefit from the experience of MARELCO in energy generation and distribution as well as the necessary stakeholder management on the side of the municipal government.

While the implementation of biomass-to-energy systems on Marinduque represents a paradigm shift away from traditional fossil fuel (and thus linear) economic models, it does not necessarily represent a threat to any established stakeholder.

Regional Added Value

The previous section identified the economic added value on a project level (NPV, IRR) and the regional added value (1.1 million EUR per year) and has shown that changing from BAU diesel energy generation to biomass cogeneration yields financial added value to the region. The utilization of domestic material and energy potentials has freed domestic capital that can now be kept within the region instead of exported to pay for diesel fuel. However, the RAV from the project extends beyond the traditional economic sense. The next section analyses the additional RAV potentials from a social and environmental standpoint, further highlighting the benefits of the adoption of regenerative energy strategies on Marinduque.

Regional Added Value: Environmental Perspective

Biomass-to-Energy systems have the potential to offset both local and macro-environmental damages caused by fossil fuel electricity generation.

Local Environmental Factors

The substitution of diesel fuel with regional biomass potentials as a source of electricity has the potential to mitigate local environmental damages. The main environmental concerns involved with the BAU scenario are unintentional spills and seepage of diesel into the soil and water.

Firstly, spills or seepage on-site at the Boac diesel generator have the potential to damage the marine habitat in the local area affecting ecosystem services and marine wildlife. The damage to underwater ecosystems further affects the livelihood of local fishermen and sustenance fishing in the area. Secondly, diesel fuel must be transported to the island on barges and ferries. The transit of barges through the channel between the mainland and Marinduque further effects the marine ecosystem in this area, albeit outside of the regional system analyzed here. Replacing diesel fuel consumption with local biomass not only substitutes the fossil fuel consumed at Boac but also the energy requirements for transportation of the fuel while mitigating the impact on local marine environments.

Macro Environmental Factors

When burned, fossil fuels release stored carbon in the form of carbon dioxide (CO_2) into the atmosphere. The combustion of biomass on the other hand, emits CO_2 into the atmosphere at the rate associated with its natural decomposition. Because the absorption and release of Carbon by biomass is a part of the naturally occurring Carbon Cycle, the combustion of biomass for electricity is considered Carbon Neutral. By replacing diesel fuel, biomass-to-energy systems offset the CO_2 released under the BAU electricity generation scenario.

Total Emission Reductions from the Santa Cruz Project

The total baseline project emissions are the sum of the CO_2 emissions from the diesel generator and the CH_4 emissions from the decomposition of the coconut and rice biomass. Together, the project's baseline emissions are 19,460 tCO_{2e}/year or 136,222 tCO_{2e} over the first seven-year crediting period. After subtracting the project emissions from the baseline scenario, the Santa Cruz project demonstrates a GHG savings potential of 18,474 tCO_{2e}/year and 129,318 tCO_{2e} over the first seven-year crediting period.

Year	CO_2 emissions from diesel electricity generation (tCO_2/year)	CH_4 emissions from rice residue decomposition (tCH_4/year)	CH_4 emissions from coconut husk decomposition (tCH_4/year)	CH_4 and N_2O emissions from biomass co-generation (Project Emissions) (tCO_{2e}/year)	Total Emission Reductions
1	7,016	11,686	758	987	18,474
2	7,016	11,686	758	987	18,474
3	7,016	11,686	758	987	18,474
4	7,016	11,686	758	987	18,474
5	7,016	11,686	758	987	18,474
6	7,016	11,686	758	987	18,474

7	7,016	11,686	758	987	18,474

Total Emission Reductions after 7 year crediting period	**129,318**

Environmental Benefits and the Clean Development Mechanism (CDM)

Carbon Credits are traded publicly as emissions reductions for signatories to the Kyoto Protocol and thus have a market value. Certified Emission Reduction (CER) credits have traded between 4 EUR/ tCO_{2e} and 30 EUR/ tCO_{2e} and have the potential to add significant value to project owners. Despite this, the additional income potential of CER credits to the financial evaluation of the Santa Cruz project were not included in the Cash Flow and NPV analysis as the future of the Carbon Market is uncertain. Instead, this paper analyzes the 'organic' potential of the project itself, or its ability to provide a reasonable return on investment and operate without additional funding mechanisms.

While the long-term sustainability of the carbon market is uncertain, the sale of CER's has massive potential to improve financial conditions for early adopters of regenerative energy systems in the developing world. Importantly for this paper however, is the Green House Gas (GHG) abatement potential that the Santa Cruz project provides: Functioning for its CDM crediting period of 7 years, the Santa Cruz project has the potential to abate 130,000 tons of CO_{2e} gases, and over the estimated 20 year project life span, 369,480 tons of CO_{2e}, proving the macro environmental added value of the project itself.

For a detailed calculation and discussion of the GHG reduction potential based on the United Nations Framework Convention on Climate Change's (UNFCCC) Clean Development Mechanism (CDM), please see **Appendix II** of this paper.

Regional Added Value: Social Perspective

There are three main aspects to the social added value attached to the implementation the Santa Cruz of biomass-to-energy project on Marinduque.

Job Creation

Firstly, the project itself creates additional technical and managerial positions that would have otherwise not existed. Marinduque is home to a number of colleges and Universities whose graduates, more often than not, are forced to leave the island to find employment. Investment in biomass-to-energy systems, like the Santa Cruz project, creates both technical and managerial positions with internationally competitive salaries. At 3,253 EUR per person per year (CIA World Factbook, 2012), the average GDP per capita is nearly trebled in the case of project technicians and exceeded by six times for the case of managers and engineers under the project financial assumptions. The Santa Cruz project creates value added employment for skilled workers, increasing income and spending on the island while helping to prevent the export of educated workers.

Purchasing Power

Under the BAU scenario, the people of Marinduque export their financial earnings from domestic value added activities to pay for electricity from diesel fuel. By lowering the cost of electricity, the Santa Cruz project reduces the cost of electricity by 613,880 EUR/year, distributed among all energy consumers. This financial saving frees up more personal income for investment opportunities as well as inevitably increasing living standards as a result.

Furthermore, the total price paid for electricity by consumers is no longer exported off of the island (save for the initial repayment on debt and equity). The total project revenue from the sale of electricity, 2,413,407 EUR/year is instead paid to domestic project owners, who both redistribute the earnings in terms of employment, taxes and the purchase of raw materials from farmers, keeping financial flows within the region, reducing the export of domestic capital.

Finally, the Santa Cruz biomass-to-energy project creates additional revenue streams for local farmers. By revaluing agricultural waste streams, farmers have the opportunity to further increase their annual income. At a price of 50 EUR per ton of raw material, the combined increase of purchasing power distributed amongst the farmers of Santa Cruz is equal to 495,706 EUR/year.

The increase in purchasing power not only helps to reduce poverty among the island's poorest members but also creates a virtuous cycle of investment and reinvestment within the community. For example, an additional revenue of 100 EUR/year may be spent on food or supplies purchased from vendors in the market. The money may also be spent reinvesting in agricultural capital, which in turn has the potential to increase productivity and thus further increase purchasing power.

HDI and Availability of Electricity

As described in Part I of this paper, the availability of electricity leads to direct increases in HDI ratings. Under the BAU scenario, MARELCO is unable to provide a consistent level of electricity from its diesel generator in Boac. The implementation of biomass-to-energy systems, like the Santa Cruz project has the ability to supplement energy losses accrued under the BAU scenario. Increasing energy security by maximizing regional material and energy potentials, biomass-to-energy systems help to create energy security within the region, and in accordance with the discoveries from the UNDP, have the potential to dramatically increase social welfare as represented by increases in HDI rating.

Additional RAV Potentials: System Optimization and Re-investment Potentials

RAV created by the Santa Cruz project and biomass-to-energy systems on Marinduque has the potential to extend beyond the direct causality relationships as described above. This section briefly examines the future added value potentials of the Santa Cruz project

Advanced System Copra Processing

The integration of biomass-to-energy systems on Marinduque requires a change in traditional practices. Traditionally on Marinduque, coconut meat is smoke cured in open-air kilns to produce copra. In this practice, halved, fresh coconuts are stacked on top of a palm frond grate, over a fire pit. Using the coconut husks as fuel, the fresh meat is cured and preserved by the smoke. The cured coconut meat, or copra, is then sold to copra dealers who in turn sell the copra to coconut oil producers on the mainland. While the traditional curing process is effective, it is both energy inefficient and typically yields copra losses of 10% due to incomplete curing and rot. Biomass fired heat and electricity cogeneration has the potential to add further value through the implementation of a mechanical hot-air copra drying system as shown below:

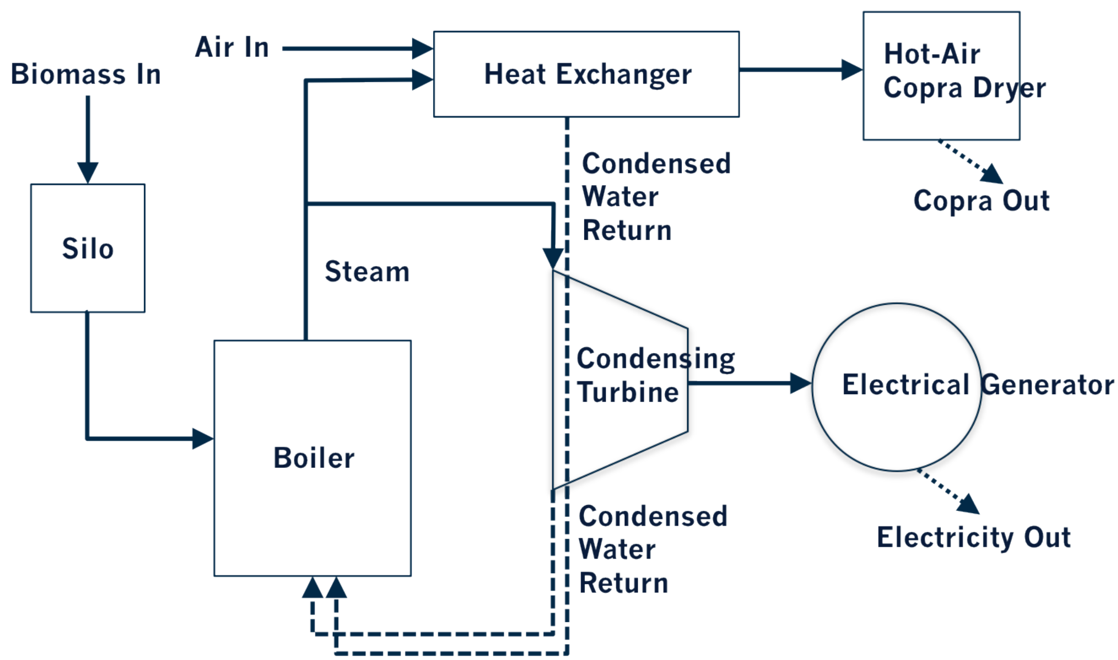

Figure 10: Technical Schematic of Biomass Co-generation System Including Electrical Generation and Hot-Air Copra Dryer

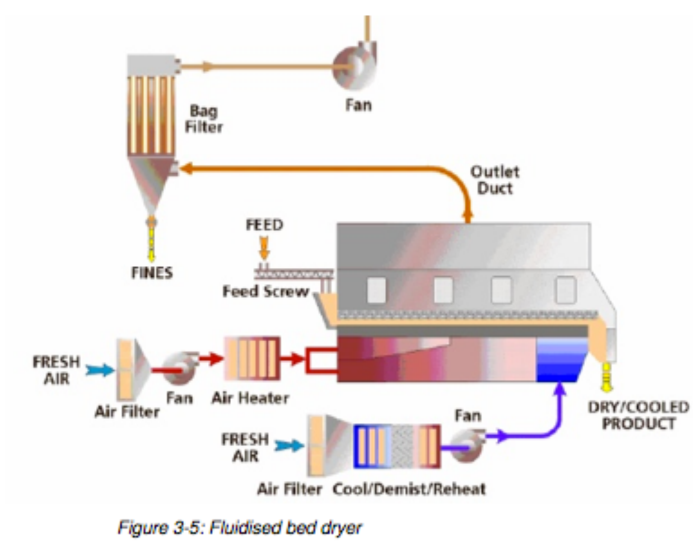

Figure 11: Fluidized Bed Copra Dryer Schematic (Devki Energy Consultancy Pvt. Ltd.,, 2006, p. 13)

Utilizing waste heat from the combustion of biomass has three distinct advantages. Firstly, the coconut husks that were used to smoke the meat traditionally are freed for use in electricity generation, yielding the added values as described above. Secondly, copra waste caused by the imperfect curing of the coconut meat is almost completely eliminated, leading to an increase of up to 10% in revenue to the coconut farmers. Finally, as the end product copra has been cured with hot air instead of smoke, the meat maintains its pure white flesh rather than the signature smoke stain. Pure white copra has the potential to garner a higher price on the open market as it can be used in a larger variety of products (i.e. desiccated coconut shavings and other food products). The added value of using hot-air dryers from waste heat over traditional kiln smoking techniques should theoretically provide the added incentive for universal implementation.

Tertiary coconut industry

Further added value scenarios become possible as a result of the biomass-to-energy scenario described above. By freeing up financial flows for investment, creating energy security and high value end products, the domestication of the value added chain for coconut products through expansion into tertiary industry becomes possible.

Local entrepreneurs have the opportunity to create downstream, added value products from their high-grade copra such as coconut oil, soap and beauty products. For example, the market value of 1 Ton of copra is 39,929 PHP (681 EUR). 1 Ton of copra can produce approximately 600kg of coconut oil. The market value of which can reach 54,158 PHP (923 EUR). The inclusion of the secondary industry of coconut oil manufacture yields a financial added value of approximately 74%.[10] Furthermore the domestic manufacture of soap and other beauty products for export, based on coconut oil, can increase the domestic value added chain adding to the overall growth perspectives on the island.

Economic, Social, Environmental and Future RAV Summary

This paper has outlined the energetic, technical, financial, environmental and social imperatives of implementing biomass-to-energy systems on Marinduque and has made the case for the long term added value of investing in the sustainable development of regional energy potentials and the creation of circular economies. The following is a summation of the RAV streams that are created through the adoption of biomass-to-energy systems following the design of the Santa Cruz project as described in Part II of this paper.

Economic Added Value	
Investor	Under the assumptions given, an investment of 4,177,051 EUR yields an IRR of 8% and an Return on Investment (ROI) of

[10] Values obtained from "Index Mundi", Online available: http://www.indexmundi.com/commodities/ using prices from April – October 2011 and exchange rates from Nov. 11th 2011.

	158% over the 20 year lifetime of the project
Electricity Consumer	By providing electricity for 0.20 EUR/kWh compared to the 0.27 EUR/kWh under the BAU scenario, electricity consumers have a combined savings of 613,880 EUR/year.
Farmers	Through the revaluation of coconut and rice agricultural residues for its use in biomass-to-energy cogeneration, an additional revenue stream of 495,706 EUR/year is injected into the local economy through the sale and purchase of these residues.
Marinduque	The financial gains to the consumer and the farmer are furthermore of financial benefit to the whole island as this money is kept within the region rather than exported to pay for fuel. Under the Santa Cruz project, a combined total of 1,109,587 EUR/year is available for investment and reinvestment locally

Environmental Added Value	
Local Environmental Benefits	By replacing diesel fuel consumption, potential damage to local waterways and marine ecosystems due to seepage and spills is reduced. The increased health of the marine ecosystem also reflects on the livelihood of fishermen and sustenance fishing on the island
Global Environmental Benefits	By displacing diesel fuel consumption and preventing the anaerobic degradation of agricultural residues, the Santa Cruz project has the potential to reduce global GHG emissions by 18,474 Tons of CO_{2e} per year or 369,480 Tons of CO_{2e} over the estimated 20 year lifetime of the project

Social Added Value	
Job Creation	The Santa Cruz project creates direct employment, offering 4 technical positions, 1 Engineering position and 1 management position, all at internationally competitive salaries

Purchasing Power	Due in part to the reduction in electricity prices and the purchase of agricultural residues from farmers, the purchasing power of all people supplied by electricity from the Santa Cruz project is increased
HDI	By maximizing regional energy potentials and creating a circular economic system on the island, the added value of increased energy security brings with it increases is standard of living as measured by an increase in HDI rating

Additional Regional Added Value Potentials	
Advanced System Copra Processing	Utilizing waste heat from biomass cogeneration allows coconut farmers to produce a better quality copra and eliminate losses due to rot from the imperfect curing of coconut meat on traditional smoke kilns
Tertiary Coconut Industry	Increased energy security and purchasing power combined with improved quality of copra creates the additional opportunity for domestic investment is tertiary coconut product industry. Investment in production capacity further up the value added chain helps to maximize regional material potentials and prevents the export of materials to foreign value added manufacturers.

Conclusions

Remote communities and in particular, islands, face the greatest challenges in the consistent provision of affordable energy. Limited and dwindling fossil resources must be imported at great cost, which combined with steadily increasing prices creates a lack of energy security. This uncertainty affects not only the quality of life for the inhabitants, but also the ability of these communities to develop. This cycle of negative reinforcement contributes to economic stagnation and systemic poverty that is difficult to escape. Under linear economic models, these communities are forced to import fossil fuels from foreign producers, exporting financial capital to pay for these services. The continual cycle of debt and payment retards the economic growth within the region at the expense of providing basic quality of life services.

Under circular economic models, regional material and energy flows are identified using tools such as Material Flow Management. The activation of these regional potentials helps to create regional added value throughout economic, social and environmental levels. Through investment in the sustainable use of regional energy potentials, a circular economic model is formed, creating opportunities for reinvestment within the region, helping to create a virtuous cycle of sustainable growth.

In this paper, the example of Santa Cruz, Marinduque, Philippines is used to show that the investment in biomass-to-energy systems has the potential to yield multiple added value streams. Not only does the project show organic (un-subsidized) profitability, but also helps to create value within the region on environmental and social levels, breaking the traditional linear economic model of debt and payment while increasing energy security and accordingly, quality of life.

By identifying and activating the biomass energy potential on Marinduque, this paper has shown the financial added value effect that such an approach would have on the region. By freeing up domestic capital, the project as posited in this paper creates the possibility for re-investment within the region and the ability to implement multiple regenerative energy systems such as wind and solar, which were beyond the scope of the paper and not discussed in detail. This virtuous cycle has the potential to create incrementally greater energy security and eventually a 100% energy secure island through the maximization the island's regional material and energy potential, completely replacing diesel generation requirements.

It is the goal of this report to prove that the implementation of regenerative energy systems do not just yield macro environmental benefits through the reduction of greenhouse gases, but create added value that permeates throughout a region on both economic and social levels. While not all regenerative energies have reached grid parity, the continuous increase of fossil energy prices combined with the volatility of supply, steadily bring the price points closer together. In the case of remote communities and islands, where energy security and the supply of affordable electricity are vital, regenerative energy systems that maximize domestic material and energy flows can help to break linear economic models and systemic poverty.

Remote communities and islands are on the forefront of the battle against climate change. The willingness of these communities to adopt sustainably managed regenerative energy systems will help not only on a domestic level but will help break the trail for the rest of the world to follow.

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Appendix I

Cash Flow Analysis

Year	0	1	2	3	4	5	6	7	8	9	10
Capex	4,177,051	0	0	0	0	0	0	0	0	0	0
Costs											
Equity	0	183,790	183,790	183,790	183,790	183,790	-	-	-	-	-
Debt	0	438,590	438,590	438,590	438,590	438,590	438,590	438,590	438,590	-	-
Materials	0	495,706	495,706	495,706	495,706	495,706	495,706	495,706	495,706	495,706	495,706
O&M	0	417,705	417,705	417,705	417,705	417,705	417,705	417,705	417,705	417,705	417,705
Personel	0	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000
SUM	4,177,051	1,615,792	1,615,792	1,615,792	1,615,792	1,615,792	1,432,002	1,432,002	1,432,002	993,411	993,411
Revenues											
Sales	0	1,753,944	1,753,944	1,753,944	1,753,944	1,753,944	1,753,944	1,753,944	1,753,944	1,753,944	1,753,944
Cash Flow	(4,177,051)	138,152	138,152	138,152	138,152	138,152	321,942	321,942	321,942	760,532	760,532

Year	11	12	13	14	15	16	17	18	19	20
Capex	0	0	0	0	0	0	0	0	0	0
Costs										
Equity	-	-	-	-	-	-	-	-	-	-
Debt	-	-	-	-	-	-	-	-	-	-
Materials	495,706	495,706	495,706	495,706	495,706	495,706	495,706	495,706	495,706	495,706
O&M	417,705	417,705	417,705	417,705	417,705	417,705	417,705	417,705	417,705	417,705
Personel	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000	80,000
SUM	993,411	993,411	993,411	993,411	993,411	993,411	993,411	993,411	993,411	993,411
Revenues										
Sales	1,753,944	1,753,944	1,753,944	1,753,944	1,753,944	1,753,944	1,753,944	1,753,944	1,753,944	1,753,944
Cash Flow	760,532	760,532	760,532	760,532	760,532	760,532	760,532	760,532	760,532	760,532

NPV €33,080
IRR 8%
ROI 1.58

discount rate - r % 8%

Appendix II

CO_2 Equivalent Emissions and the Clean Development Mechanism

The Kyoto Protocol (KP) Clean Development Mechanism (CDM) from the United Nations Framework Convention on Climate Change (UNFCCC) is a project-based program that awards carbon credits that are bought and sold on the open market, to certified projects that reduce GHG emissions. Projects must prove that they are "additional", meaning that the emission reduction credits provided to the project operators will provide funding that without which, the project could not take place. The amount of credits that a project is eligible for is outlined further in the full guidelines from the UNFCCC for CDM project development and are available online at their website: http://cdm.unfccc.int/.

Emission Reduction Potential

Replacing Electricity From Diesel Generation

The emission reduction calculation is based on Appendix B simplified modalities and procedures for small scale CDM projects, Section I.D. paragraph 6, which states that "For a system where all generators use exclusively fuel oil and/or diesel fuel, the baseline is the annual kWh generated by the renewable unit times an emission coefficient for a modern diesel generating unit of the relevant capacity operating at optimum load as given in table I.D.1." (UNFCC, 2005, p. 12) The figure from table I.D.1. is 0.8 $kgCO_2/kWh$ for a unit over 200kW operating at any load rate.

The project is set to reduce electricity supplied by diesel generation by 8,770 MWh/year through the use of the biomass combustion unit. At a standard Carbon Emission Factor (CEF) of 0.8 $kgCO_2/kWh$ from diesel electricity generation, the annual CO_{2e} emission savings from diesel electricity generation is 7,016 TCO_{2e}/year.

$$8{,}770\ \text{MWh/year} \times 0.8\ \text{kgCO}_{2e}\text{/kWh} \times 1000\ \text{kWh/MWh} \times 0.001\ \text{t/kg} =$$

$$7{,}016\ \text{tCO}_{2e}\text{/year}$$

Methane Emission Reduction From Rice Residue Combustion

Emissions from the natural decay of rice husk and straw is measured according to Appendix B simplified modalities and procedures for small scale CDM projects, Section III.E. Avoidance of methane production from biomass decay through controlled combustion (UNFCC, 2005, p. 32). The formulae used for the calculation of emissions from the natural decomposition of rice residues is as follows:

CH4_IPCCdecay = (MCF * DOC * DOCF * F * 16/12)

Where:

CH4_IPCCdecay	IPCC CH4 emission factor for decaying biomass in the region of the project activity (tons of CH4/ton of biomass or organic waste)
MCF	methane correction factor (fraction) (IPCC default value is 0.4)
DOC	degradable organic carbon (IPCC default value is 0.3)
DOCF	fraction DOC dissimilated to gas (IPCC default value is 0.77)
F	fraction of CH4 in gas (IPCC default value is 0.5)

BEy = Qbiomass * CH_4_IPCCdecay * GWP_CH_4

Where:

BEy	Baseline methane emissions from biomass decay (tons of CO2 equivalent)
Qbiomass	Quantity of biomass treated under the project activity (tons)
CH4_GWP	GWP for CH4 (tonnes of CO2 equivalent/ton of CH4)

CH4_IPCCdecay = (MCF * DOC * DOCF * F * 16/12)

CH4_IPCCdecay = 0.4 x 0.3 x 0.77 x 0.5

CH4_IPCCdecay = 0.0616 TCH_4/TBiomass

BEy = Qbiomass * CH_4_IPCCdecay * GWP_CH_4

BEy (t/year) = QBiomass (t/year) x CH_4_IPCCdecay (tCH_4/t) x GWP_CH_4 (tCO_2/tCH_4)

BEy (t/year) = 9,034 (t/year) x 0.0616 tCH_4/tBiomass x 21 tCO_2/tCH_4

BEy (t/year) = 11,686 tCO_2/year

(UNFCC, 2005, p. 33)

Methane Emission Reduction From Coconut Husk Combustion

Emissions from the natural decomposition of coconut husk are calculated according to Appendix B simplified modalities and procedures for small scale CDM projects, Section III.E. Avoidance of methane production from biomass decay through controlled combustion (UNFCC, 2005, p. 32). The formulae used for the calculation of emissions from the natural decomposition of coconut husk is as follows:

$$CH4\_IPCCdecay = (MCF * DOC * DOCF * F * 16/12)$$

Where:

CH4_IPCCdecay	IPCC CH4 emission factor for decaying biomass in the region of the project activity (tons of CH4/ton of biomass or organic waste)
MCF	methane correction factor (fraction) (IPCC default value is 0.4)
DOC	degradable organic carbon (IPCC default value is 0.3)
DOCF	fraction DOC dissimilated to gas (IPCC default value is 0.77)
F	fraction of CH4 in gas (IPCC default value is 0.5)

$$BEy = Qbiomass * CH_4\_IPCCdecay * GWP\_CH_4$$

Where:

BEy	Baseline methane emissions from biomass decay (tons of CO2 equivalent)
Qbiomass	Quantity of biomass treated under the project activity (tons)
CH4_GWP	GWP for CH4 (tons of CO2 equivalent/ton of CH4)

QBiomass

The amount of biomass available is 880 T/year, however because roughly one third of the coconut husks are used in the baseline scenario for copra drying in traditional kilns, they have to be subtracted from the emission calculations. Therefor, for the value Qbiomass for CH_4 emission reductions from the controlled combustion of coconut husks only one third of the 880 T/year is used. Thus, Qbiomass for coconut husks is 586 T/year.

$CH4\_IPCCdecay = (MCF * DOC * DOCF * F * 16/12)$

$CH4\_IPCCdecay = 0.4 \times 0.3 \times 0.77 \times 0.5$

$CH4\_IPCCdecay = 0.0616\ tCH_4/tBiomass$

$BEy = Qbiomass * CH_4\_IPCCdecay * GWP\_CH_4$

BEy (t/year) = QBiomass (t/year) x CH_4_IPCCdecay (tCH_4/tbiomass) x GWP_CH_4 (tCO_2/tCH_4)

BEy (t/year) = 586 (t/year) x 0.0616 tCH_4/tBiomass x 21 tCO_2/tCH_4

BEy (t/year) = 758 tCO_2/year

(UNFCC, 2005, p. 33)

The total baseline project emissions are the sum of the CO_2 emissions from the diesel generator and the CH_4 emissions from the decomposition of the coconut and rice biomass. Together, the project's baseline emissions are 18,474 tCO_{2e}/year or 129,317 tCO_{2e} over the first seven-year crediting period. This number does not include the project emissions.

Santa Cruz Project Emissions

Project emissions from the combustion of biomass used for electricity generation are measured according to the following formula which can be found in Appendix B simplified modalities and procedures for small scale CDM projects, section III.E. Paragraph 5, version 7 (UNFCC, 2005, p. 32):

$PE_y = Q_{biomass} * E_{biomass} (CH_4bio\_comb * CH_4\_GWP + N_2Obio\_comb * N_2O\_GWP)/10^6$

Where:

PE_y Project activity emissions (kilotons of CO_2 equivalent)

$Q_{biomass}$ Quantity of biomass treated under the project activity (tons)

$E_{biomass}$ Energy content of biomass (TJ/ton)

CH_4bio_comb CH_4 emission factor for biomass and waste (which includes dung and agricultural, municipal and industrial wastes) combustion (kg of CH_4/TJ, default value is 300)

CH_4_GWP — GWP for CH_4 (tons of CO_2 equivalent/ton of CH_4)

N_2Obio_comb — N_2O emission factor for biomass and waste (which includes dung and agricultural, municipal and industrial wastes) combustion (kg/TJ, default value is 4)

N_2O_GWP — GWP for N_2O (tons of CO_2 equivalent/ton of NO_2)

Project Emissions from Rice Husk and Straw Combustion

$$PEy = 9{,}034 \text{ t/year} \times 0.0134 \text{ TJ/t } (300 \times 21 + 4 \times 310) / 1000 \text{ kg/t}$$

$$PEy = 913 \text{ tCO}_{2e}\text{/year}$$

Project Emissions from Coconut Husk Combustion

$$PEy = 586 \text{ t/year} \times 0.0167 \text{ TJ/t } (300 \times 21 + 4 \times 310) / 1000 \text{ kg/t}$$

$$PEy = 74 \text{ TCO}_{2e}\text{/year}$$

Total Project Emissions

$$PEy = 987 \text{ TCO}_{2e}\text{/year}$$

Total Emission Reductions from the Santa Cruz Project

The total baseline project emissions are the sum of the CO_2 emissions from the diesel generator and the CH_4 emissions from the decomposition of the coconut and rice biomass. Together, the project's baseline emissions are 19,460 tCO_{2e}/year or 136,222 tCO_{2e} over the first seven-year crediting period. After subtracting the project emissions from the baseline scenario, the Santa Cruz project demonstrates a GHG savings potential of 18,474 tCO_{2e}/year and 129,318 tCO_{2e} over the first seven-year crediting period.

Year	CO_2 emissions from diesel electricity generation (tCO_2/year)	CH_4 emissions from rice residue decomposition (tCH_4/year)	CH_4 emissions from coconut husk decomposition (tCH_4/year)	CH_4 and N_2O emissions from biomass co-generation (Project Emissions) (tCO_{2e}/year)	Total Emission Reductions
1	7,016	11,686	758	987	18,474

2	7,016	11,686	758	987	18,474
3	7,016	11,686	758	987	18,474
4	7,016	11,686	758	987	18,474
5	7,016	11,686	758	987	18,474
6	7,016	11,686	758	987	18,474
7	7,016	11,686	758	987	18,474

Total Emission Reductions after 7 year crediting period	**129,318**